CRATER SIZE-FREQUENCY DISTRIBUTIONS ACCUMULATED ON EJECTA BLANKETS OF FRESH PRIMARY CRATERS ON VESTA

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Introduction: The Dawn spacecraft, which has already delivered a large amount of data of the third largest and second most massive body in the asteroid belt, Vesta, is now on its way to the dwarf planet Ceres. While the Dawn team is gradually preparing for the arrival at Ceres in April 2015, the analyses of Vesta data is still under way. During last year's LPSC we have already presented size-frequency distributions (SFDs) of sub-kilometer impact craters measured on few fresh surface units on Vesta and compared them with the two currently published production functions (PFs) of [1] and [2]. Since results of the analyses of these few and often very small surface units do not allow for a universally valid conclusion, we expanded our crater catalogue of investigated fresh <40 km primary craters respectively their ejecta blankets, which represent some of the youngest surface units on Vesta.

Methodology: SFDs of small craters, under some circumstances, can be very susceptible because small craters are the first ones to be affected by subsequent modification ([3], [4] and [5]). This includes (among other processes) an admixture of secondary craters which, due to the specific shape of the SFD of ejected projectiles and the inverse relation between the spall size and ejection velocity ([6], [7] and [8]), can considerably increase the numbers of small craters. On the other hand, degradation processes on Vesta, primarily caused by impact-induced seismic shaking, which destabilizes slopes and triggers mass wastings, will reduce the numbers of small craters when compared to larger ones. Since the influence of both processes largely depends on the age (the older a surface, the higher the probability that modification has occurred), we investigate especially young or fresh surface units whose superposed CSFDs should most likely reflect the mass-velocity distribution of impacting meteorites.

Till now, we have investigated CSFDs superposed on ejecta blankets and sometimes also on the interior deposits of 42 fresh craters on Vesta. Primary craters have been classified as fresh provided that they exhibit two of the following properties: (1) a distinct, sharp crater rim and/or fresh exposed crater walls with "spur-and-gully" morphology, (2) a relatively low density of small craters superposed on the corresponding surface units (ejecta blankets) and (3) a conspicuous spectral signature in Framing Camera (FC) color ratio data.

In order to measure CSFDs we performed crater counts within ESRI's ArcGIS by using the *CraterTools* [9] extension which allows comfortable and most accurate measuring of areas and impact crater diameters by automatically solving the problem of map-projection related distortions. Additionally, its newer version [10] also allows for automated correction of topography-related crater and area distortions, which occur when the actual shape of the investigated body highly deviates from the used reference ellipsoid used for the map projection. For the analyses of CSFDs and the derivation of absolute model formation ages, we used the software *Craterstats* by [11], [12]. Additionally, we have estimated the amount of mass ejected for certain crater sizes on Vesta in comparison to Mars and the Moon using the most recent version of the widely accepted cratering model of [13]. In this way, under consideration of spallation models of [6], [14], [8] and [15] and impactor-crater scaling laws by [16], [17], we are able to make at least a rough estimate of the SFD of ejected fragments that are capable of forming secondary craters.

Results: As Fig 1 shows, the relation between the ejected mass and the corresponding ejection velocity is quite different for an impact that produces a crater of the same size on our three target bodies. The velocity v_{sec} at

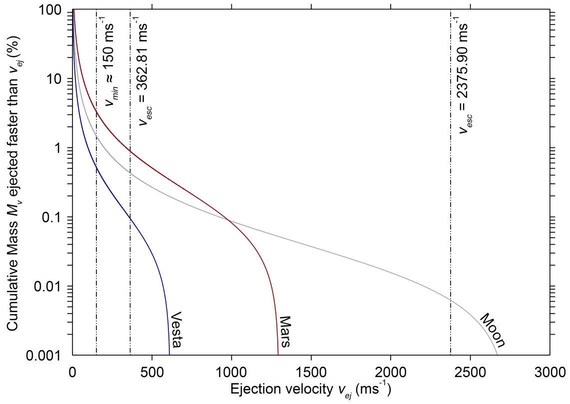

Figure 1: Cumulative Mass M_v (%) ejected faster than v_{ej} plotted versus the ejection velocity v_{ej} (ms^{-1}) for a Vibidia sized impact (rim diameter $D_r = 6.39$ km) on various planetary bodies (Vesta, Mars and the Moon). Note that different sized impactors are necessary to form craters of the same size on our three bodies primarily due to differences in impactor velocity, target density and gravitational conditions.

which traditional secondary craters might form is limited by a minimum velocity v_{min} and the escape velocity v_{esc} ($v_{\mathrm{min}} < v_{\mathrm{sec}} < v_{\mathrm{esc}}$). Regardless of v_{min} (~150 - 250 ms^{-1} on Jupiter's moon Europa [18]), v_{sec} is way much smaller on Vesta than on Mars or the Moon as a consequence of low v_{esc} values. According to our Vibidia ejecta modeling results, only a very small fraction (~0.5 %) of the mass is ejected at v_{sec} provided that $v_{\mathrm{min}} = 150$ ms^{-1}, while ~0.1 % ecapes from Vesta. In summary, we would expect fewer secondary craters on Vesta that potentially contaminate CSFD measurements when compared to larger bodies with higher gravitational acceleration and/or higher impact velocities.

The smallest of the investigated primaries, an unnamed 1.13 km crater at 26.16°S/14.63°E exhibits an ejecta blanket, which is too small to obtain reliable statistics. As a general rule, all investigated primaries ≲3 km in diameter have ejecta blankets with exeedingly low numbers of superposed small craters due to small areal extent and/or a very young formation age and thus do not allow any reliable statement.

CSFDs over a limited diameter range generally follow a power-law of the form $N \sim D^{a}$ with N as the number of craters of diameter D and a as the power-law exponent. It appears from the various analyses, which we performed that SFDs of craters between D(80 m, 1 km) exhibit power-law exponents between -4.0 to -4.2 (differential), (see Fig 2) or -3.0 to -3.2 (cumulative), which almost exactly describes the course of the lunar-like PF of [2] within the same diameter range. The consequence that arises from this is that all CSFDs investigated on relatively fresh surface units run significantly steeper than the asteroid-flux derived model PF (MPF) of [1], which has an average power-law exponent of approx. -3.54 (differential) between D(80 m, 1 km). SFDs of craters below 80 m measured on ejecta blankets often exhibit power-law exponents between -4.8 to -5.3 (differential) or -3.8 to -4.3 (cumulative), which indicate a certain amount of self-secondaries.

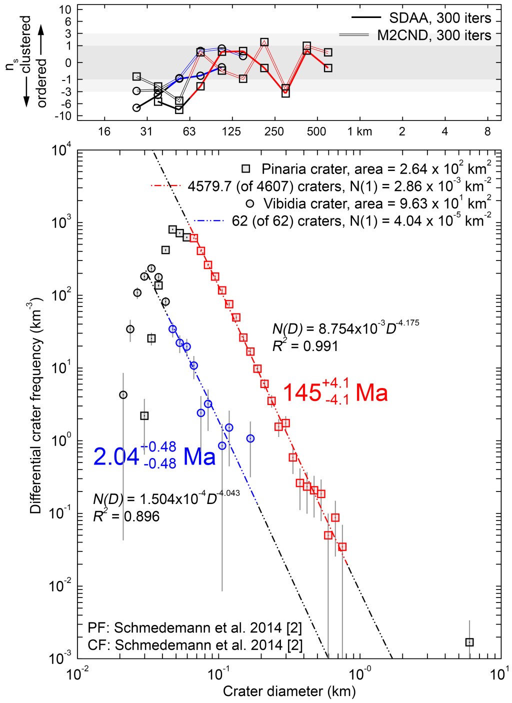

Figure 2: CFSDs obtained on ejecta blankets of one of the youngest (Vibidia) and one of the oldest (Pinaria) investigated craters in differential presentation. The upper plot shows the results of two individual randomness analyses methods namely a *standard deviation of adjacent area* (SDAA) and a *mean 2nd closest neighbor distance* (M2CND) [11], [12] to gain an insight into the spatial distribution of craters within the measurement area.

Fig. 2 shows fits (dashed lines) of the lunar-like PF [2] to data bins and derived absolute model formation ages of Vibidia and Pinaria crater and power-law functions modeled using least squares simple linear regression with coefficient of determination R^2 values. The derived power-law function for Vibidia data bins $N(D) = 1.504\mathrm{x}10^{-4} D^{-4.043}$ between D(47.3, 118.8 m) exhibits a lower R^2 value due to data scattering as a consequence of low statistics for craters with $D \gtrsim 100$ m when compared to those of Pinaria with $N(D) = 8.754\mathrm{x}10^{-3} D^{-4.175}$ and $R^2 = 0.991$ between D(66.6, 749.9 m). For comparison, the differential form of the lunar-like PF [2] and the asteroid-flux derived MPF [1] can be approximated by $N(D) = D^{-4.043}$ and $N(D) = D^{-3.439}$ respectively for D(47.3, 118.8 m) and $N(D) = D^{-4.209}$ and $N(D) = D^{-3.542}$ respectively for D(66.8, 749.9 m). If our assumptions about the pristine and undisturbed condition of CSFDs measured on the investigated young surface units are correct, the lunar-like PF [2], which best approximates the data should be a good reflection of the impactor population from a few to several hundred meters in size.

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